

EMC in a High-Frequency World

The new year brings numerous EMC challenges, such as increasing clock speeds and conformity to worldwide standards.



Donald N. Heirman is a NARTE-certified EMC engineer and president of Don Heirman Consultants (Lincroft, NJ), a training and educational EMC consultation corporation. Bringing with him more than 30 years of experience in EMC, Heirman chairs, or is a principal contributor to, multiple national and international EMC standards organizations, including ANSI ASC C63 and CISPR. Heirman is a fellow of IEEE; is a member of its EMC Society board of directors and vice president for standards; chairs the IEEE Standards Association Standards Board; is president of NACLA; and is a member of the Technical Management Committee of the U.S. National Committee for IEC, among many other contributory positions in the field of EMC. Heirman took a few minutes out of his very busy schedule to speak with assistant editor Joshua Glover about his perspectives on the current state of EMC.

Q. As clock speeds on electronic devices continue to rise, what critical technical challenges await the engineer aiming for electromagnetic compatibility (EMC) compliance?

A. Because it is only recently that clock speeds are exceeding 1 GHz, there is little public information on the subject. Common thinking is that, moving to frequencies above 1 GHz, all structures, including cabinets, enclosures, cabling, etc., can act like efficient radiators. From an antenna perspective, an effective radiator is a quarter- or a half-wavelength. At frequencies in the gigahertz region, a half-wavelength is only 24 cm (about 6 in.), meaning an antenna can be a ventilation slot, a chassis door without correctly installed radio-frequency-interference (RFI) gasketing, or even a card cage. If doors or other openings have gaps (e.g., improper fitting between the door and its mating surface) this long or longer, radio-frequency (RF) energy ingress and egress takes place—hence the need for better design for emission suppression and immunity. In other words, there is no shielding attenuation of a slot or gap when it is half a wavelength long; and once an emission from the product gets through a slot, it acts like any other wave in both its near- and far-field effects on surrounding devices. Similarly, the slot

is a receiving aperture or antenna and lets in RFI environmental noise. This in effect moves EMC design down to the printed-circuit-board level, in addition to the elimination of RFI on attached external cabling via filtering.

Q. How do increasing clock speeds affect EMC measurement?

A. EMC measurement difficulties increase as the frequencies exceed 1 GHz for several reasons:

- Product emissions tend to be in narrow beamwidths and so are difficult to find.
- Measuring antennas tend to have narrower beamwidths, making it difficult to aim and search at the limit distance away from the product and still capture the radiated signal.
- Instrumentation such as spectrum analyzers and receivers must pick up low-level signals at typical limit distances of 3 and 10 m between the antenna and the product under test.
- Antenna-to-receiver cables become much more lossy, affecting the ability to measure signals above the noise floor of the spectrum analyzer or receiver.
- More time is required to find the maximum emissions, due to the

Interview

necessity of manual searching as the product cycles through its operating modes.

- Product immunity to incident radiated fields is more difficult to assess due to the narrow beamwidth and the product's apertures, such as cable ports and slots.

Q. How does IEEE address needed standards work in areas

such as the influence of increasing clock speeds on EMC?

A. IEEE is comprised of over 30 technical societies, including the IEEE EMC Society (EMCS), in turn made up of technical committees that deal with technology in a specific subject area. When standards are needed, the appropriate technical committee (TC), in this case the EMCS TC-4, Electromagnetic

Interference Control, works with the society's Standards Development Committee to develop a standard. The writing and revising of standards, including studies of possible areas requiring standards, is a continual process.

Higher clock frequencies are also currently being discussed in the EMCS annual symposia. The next symposium is set to take place in Montreal in August 2001, and TC-4 is sponsoring several technical sessions on EMC design. The symposium in Washington, DC, this past August is another resource for the latest papers on the subject.

Q. How is the proliferation of portable electronic devices and wireless communications devices affecting EMC compliance?

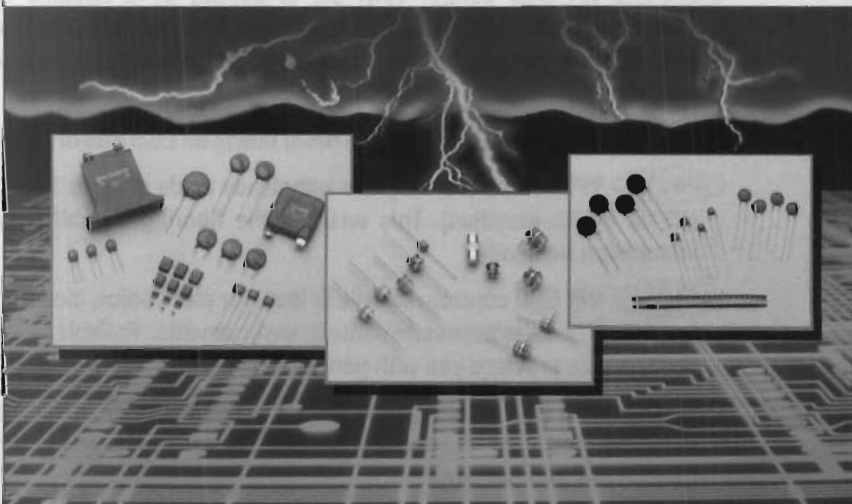
A. Any time you have more sources of RF energy, the EMC design must accommodate with greater immunity. One area of growth is the use of the 2.45 GHz band, where such activity as Bluetooth, cordless phones, HomeRF, new RF lighting, and other systems are all vying for use and must work with each other's ambients. The proponents of these devices are thus concerned with interference from other devices using the same band. There have been claims of interference, but this situation is still coming to a boil. It is only a matter of time before products with lesser immunity in this band will not work together at all user locations.

The 2.45 GHz band is a very active area and one where the boundary between system design and EMC is unclear. A current study within the EMCS deals with the potential for interference in this band and possible remedies for that interference. The study is being conducted jointly by TC-6 (Spectrum Management) and the Standards Development Committee. IEEE Working Group 802.15 is conducting a similar study on interference between wireless local-area-network equipment, which falls under IEEE 802.11, and Bluetooth, which 802.15 is considering standardizing. These efforts are sharing information, though at this point the facts have not been clearly established, so it is not clear that there

Formerly
Siemens



EPCOS



Arm your application with total circuit protection

Achieve surge suppression across the board with EPCOS. Whether your design is telecom, consumer or automotive, only EPCOS manufactures three families of protection devices:

Metal Oxide Varistors (SIOVs)

for fast-reacting over-voltage protection: Disc types with surge capability to 12kA; multilayer and monolithic SMDs; automotive types for applications to 125°C and 100 Joule; encapsulated block (B) and low profile epoxy-coated (LS) types for high energy and high current requirements to 100kA.

Gas Tube Surge Voltage

Protectors (SVPs) for over-voltage protection with high current capability: 3-electrode types, including fail-safe

and vent-safe options for telecom applications; 2-electrode types; plus types for communication and CATV.

Thermistors for resettable over-current, over-temperature, and inrush current protection in a broad range of currents, voltages, and switching temperatures; leaded and surface mount packages.

For total circuit protection...

Call: 800-888-7728

On the web:

www.usa.epcos.com

E-mail:

protectors.usa@epcos.com

EPCOS, Inc.
Iselin, New Jersey 08830

EPCOS®

is a need to fix anything.

This is also partially an RF spectrum allocation issue, in which the Federal Communications Commission (FCC) allows only certain services in a band as a preference. All other uses of the band, when allowed, are usually low power and are always of a secondary priority level and therefore must live with any interference they encounter, with no relief from regulators. One such allocated service is industrial, scientific, and medical (ISM) equipment, which partially falls under the 2.45 GHz band and has unlimited radiated energy at this frequency (± 50 MHz) as a priority. If manufacturers want their products to operate in this part of the spectrum, they must build more immunity or signal discrimination into those products, to create a system which does not respond to fields such as those from high-power ISM equipment.

Q. What changes in test site qualifications and testing method-

ologies can test houses and compliance laboratories look forward to in the next year?

A. The biggest challenge is how to qualify test sites used for measurement of radiated emissions above 1 GHz. The effect of the reflecting ground plane used below 1 GHz is under study for use above 1 GHz and may not be needed. If product emissions are narrowly focused and the measuring antenna also has a narrow beamwidth, does the emitted signal ever see the ground plane? If not seen, should the limit be changed because the ground reflection is not added to the direct signal? As a result of these questions, there is some suggestion that to ensure that the ground plane reflection is not considered, RF-absorbant materials should be placed on the ground plane to make a near-free-space measurement with only the direct path between the product and antenna.

American National Standards Institute (ANSI) Accredited Standards Commit-

tee (ASC) C63, Subcommittee 1, Techniques and Developments, is pursuing analytical and experimental work to determine the beamwidth peculiarities of common antennas used above 1 GHz, how to qualify a test site above 1 GHz, and how to measure for maximum emissions other than by manually scanning all product surfaces to find the narrow emissions beam, which requires an enormous amount of time. Such study has led to the discussion of alternate techniques, such as the use of reverberation chambers or gigahertz transverse-electromagnetic-mode (TEM) waveguides. These chambers and waveguides in essence measure the energy or total power from the device in free space before applying those results to determine suitable limits that might better show conformance with regulations. However, these techniques are still not fully subscribed to by regulators, but they are gaining acceptance for certain types of products, such as those that can fit inside a TEM waveguide.

F A S T • S A F E • R E L I A B L E

HT-3000

Production Line Hipot Tester

- 2000 VAC out; up to 20mA
- 2800 VDC out; up to 5mA
- Logic controlled, one button test



- Automatic & manual production line hipot testers
- Multi-point hipot testers
- Ground continuity testers
- Meets all safety agency requirements: UL, CE, IEC, TUV, CSA
- Innovative, simple to use designs; custom configurations available

GF-30AC

Hi Current AC Ground Tester

- 25A AC constant current output
- Red/green lights show immediate test results



*Free
30-Day Trial
on all products!*

Compliance West USA

www.compwest.com

San Diego, CA • 1.800.748-6224 • FAX (858) 452-1512

**PRODUCT SAFETY
TEST EQUIPMENT
BUILT WELL BEYOND**

**"THE
STANDARDS."**

HTT1

**Hipot/Continuity
Function Tester**

- Ideal for daily test equipment verification
- Easily checks ground continuity, leakage & hipot functions
- Works with any hipot or ground continuity tester



NEW!

Interview

The next area of concern for testing laboratories is the growing requirement to be accredited for conformity work worldwide. The new international standard ISO/IEC 17025 on test and calibration laboratory competency will help test houses meet this requirement. The standard, published in December 1999 with a 2000 date, is already seeing use by accrediting bodies, and widespread use of the standard will occur by the start of

2002. The American Association for Laboratory Accreditation (A2LA) and the National Voluntary Laboratory Accreditation Program (NVLAP), two U.S. accrediting bodies in the area of EMC testing, have adopted ISO/IEC 17025 to replace ISO Guide 25. By the end of the 2-year transition period, only 17025 will be used. Test houses currently have the following options: to be audited and accredited to Guide 25; to be audited and

accredited to Guide 25 with the addition of a gap analysis as to what is needed to meet 17025, in anticipation of having to meet it for the next audit; or to be audited and accredited directly to 17025.

Q. How does the International Electrotechnical Commission (IEC) affect U.S. EMC standards?

A. The IEC has two major technical committees which handle EMC: IEC TC77 and the International Special Committee on Radio Interference (CISPR). These committees have U.S. participation from a variety of sources, including product manufacturers, testing laboratories, academia, and regulators, all of which provide input that affects committee decisions. Especially affected are U.S. manufacturers that sell internationally, because IEC standards, translated into European norms, must be met before their products can be imported into Europe.

Since most companies are multinational and many countries are using IEC/CISPR standards as the basis for their regulatory systems, these standards must be met at some point. The ASC C63 committee is publishing pertinent IEC/CISPR standards with U.S. forwards, to state any U.S. differences or areas not applicable. CISPR 22, on emission measurements and limits of information technology equipment, is now available in the United States without going to a European source, and more such publications are on the way.

Q. How has the EMC Directive affected U.S. electronic-device manufacturers?

A. This affects U.S. manufacturers in that they not only have to meet RF emissions but also an array of immunity requirements not mandated in the United States. FCC has been more concerned with protecting the radio spectrum than with immunity, as immunity is considered a self-correcting product quality issue. In other words, if a manufacturer has a product that does not work in its RF environment, then that manufacturer will not stay in business or will get many complaints. However, it may take time for these issues to surface. For the Euro-

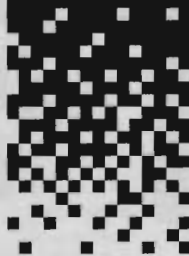
SCHLEGEL EMI SHIELDING SURVIVAL TIP # 42:

Harsh Environments? Schlegel Stands Up.



Schlegel®

EMI
Shielding
Products



www.schlegel.com

We're innovative by nature. Advanced coatings. A huge flock of profiles. Versatile attachment options. Even a new Hybrid gasket that protects against the elements and EMI. So make the natural selection. Specify Schlegel.

Because It Has To Be Right

Schlegel Systems, Inc.

Rochester, NY 14623

Telephone: 1-800-204-0863

Fax: 716-475-9758

E-mail: emiproducs@schlegel.com

UniPoly

pean Union (EU), the EMC directive mandates that products have intrinsic immunity and not cause interference—no choice left to the manufacturer. The U.S. allows more latitude and lets the marketplace rid itself of products with inadequate immunity. What this means for U.S. manufacturers offering products in Europe is that in addition to meeting common emission requirements used worldwide and based on IEC/CISPR 22

of harmonization. The IEEE-SA is an international organization, with members throughout the world active in their own country's TC77 and CISPR activities. In addition, the IEEE-SA holds the secretariat for ASC C63, which coordinates many EMC measurement standards in the U.S. and has Subcommittee 3, a technical advisory group for the U.S. for the CISPR plenary. It is through such international

representation that the IEEE-SA supports key areas of EMC standardization in multiple countries.

Donald N. Heirman can be reached at d.heirman@worldnet.att.net. For more information about ANSI, IEEE, or IEC, visit the organizations' Web sites at <http://www.ansi.org>, <http://www.ieee.org>, and <http://www.iec.ch>, respectively. ■

The EMC directive mandates that products have intrinsic immunity and not cause interference.

information technology equipment limits (which are similar to FCC limits in most of the frequency ranges), they must meet EN 61000-4-2 (ESD), 3 (radiated immunity), 4 (fast transients/bursts), 5 (surge), 6 (conducted immunity), 8 (magnetic power-fields immunity), and 11 (voltage interruptions, dips, etc.), which are based on but not necessarily identical to IEC 61000-4-2, 3, 4, 5, 6, 8, and 11. Additionally, there are power line emission requirements in Europe based on IEC 61000-3-2 (harmonics) and 61000-3-3 (flicker).

Q. How is the IEEE Standards Association (IEEE-SA) pursuing the harmonization of EMC standards?

A. The IEEE EMCS Standards Development Committee's members are all IEEE-SA members and hence work in the IEEE-SA system to get their standards published. The IEEE-SA is working on arrangements for using its standards within the IEC standardization process in several technical areas, but EMC is not currently one of these areas. IEEE-SA and EMCS members are represented on technical advisory groups for TC77 and CISPR, and some are also on the TC77 and CISPR working groups, which helps facilitate the goals



MET LABORATORIES

Baltimore, MD
410-354-3300

Raleigh, NC
919-481-9319

Union City, CA
510-489-6300

Safety EMC Telecom ESL NEBS



The World's First
Nationally
Recognized
Testing Laboratory

Tested once,
Accepted Everywhere

800-638-6057
www.metlabs.com

Case Study: Building a Bridge Between Product Safety and EMC

RICHARD GEORGERIAN AND RON DUFFY

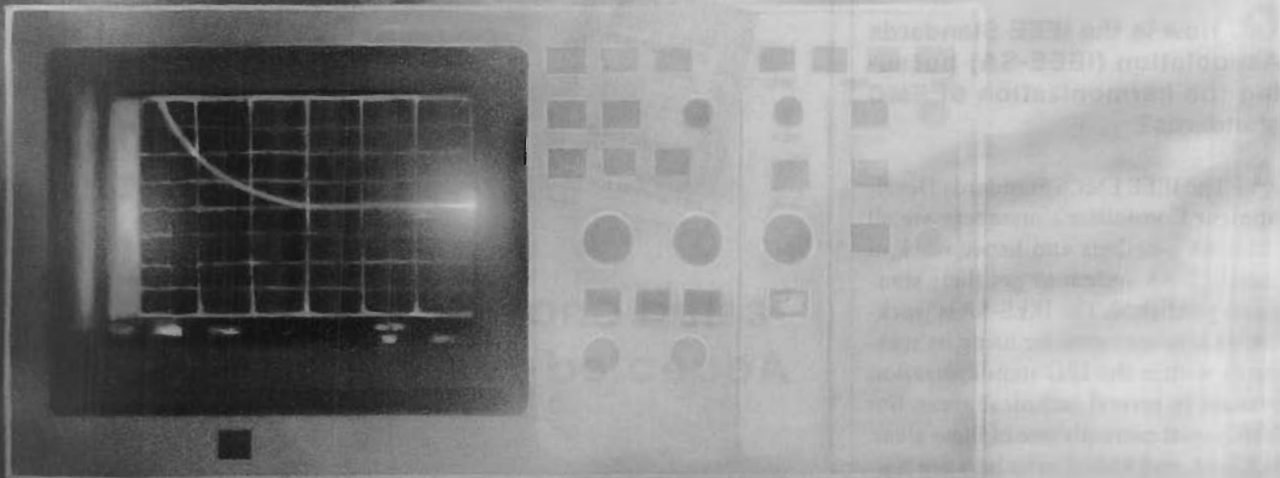
Instead of tackling product safety and EMC issues independently of each other, engineers can analyze and meet both sets of requirements together.

Line filters help products meet electromagnetic compatibility (EMC) requirements. Unfortunately, these same filters make it more difficult to meet product safety requirements. Engineers must optimize the line filter while meeting both sets of requirements, but finding a balance can be challenging. Using an ac filter as an illustration, this article examines product safety and EMC issues together. The experimental results are based on safety standards for information technology equipment (ITE) and measuring instruments. The same methods, however, can be employed with any equipment that uses a line filter, although the values would need to be adjusted to meet appropriate standards requirements.¹

The product safety analysis of an ac filter includes testing for capacitor discharge, current leakage, and dielectric strength, as well as inspection of the filter's chokes. The EMC analysis of an ac filter involves determining whether the fil-

ter provides adequate attenuation. The filter lies between the line impedance stabilization network and the intended load. By combining the product safety and conducted emissions tests, compliance engineers can determine optimum filter component values and subsequently the minimum and maximum component values for different loads.

To follow the methods used for this article, the influence of the shunt resistor, X and Y capacitors (specifically regarding capacitor discharge), current leakage, and hipot tests must first be understood. The values of the X capacitors and shunt resistor determine capacitor discharge rate. (The load, if turned on, also influences discharge rate, but for these experiments no loads were used.) The values of the Y capacitors determine the amount of current leakage from the mains power to ground. UL 1950 limits current leakage for ITE to 3.5 mA.² The Y capacitors also determine the hipot test current. There is no limit to the hipot current, but the current must be



Ac filter	V_{cap}		Physical values used in ac filter		One time constant	R1	X-capacitor system
	No.	Calculated	Measured	R1	X-capacitor system	t_c	Measured
1	149 V	147.5 V	330 k Ω	$2 \times 0.33 \mu\text{F}$	197 milliseconds	323 k Ω	0.611 μF
2	149 V	147.5 V	417 k Ω	$2 \times 0.10 \mu\text{F}$	71 milliseconds	417 k Ω	0.171 μF
3	149 V	147.5 V	1 M Ω	$2 \times 0.47 \mu\text{F}$	836 milliseconds	923 k Ω	0.906 μF
4	149 V	147.5 V	open	$2 \times 0.47 \mu\text{F}$	9 seconds	10 M Ω	0.906 μF

Table I. Capacitor discharge.

determined to properly set the hipot equipment. Setting the equipment's upper-current detection too low will result in defective operation.

Capacitor Discharge

The capacitor discharge test ensures that if an ac plug is abruptly removed from its receptacle, the voltage across the line and neutral terminals will not exceed a safe level. Per UL 1950, voltage across a capacitance greater than 0.1 μF must decay to 37% of the ac-input peak voltage in 1 second for type A equipment and 10 seconds for type B equipment. IEC 61010-1 requires that the pins not be hazardous (live) at 5 seconds after disconnection from the supply.³

Time Constant Calculation

Before each measurement, the X capacitance of the filter was measured using a network impedance analyzer. The X-capacitor value is the capacitance of the filter construction plus the parallel total of the actual values of the physical X capacitors ($C3||C4$). The resistance of the shunt resistor, $R1$, was measured with a multimeter to obtain $R1_{meas}$. $C =$ capacitance of the X-capacitor system, as listed in Table I.

$$C = (\text{capacitance of the ac filter construction}) + C3||C4 \quad (1)$$

$$\text{Time constant } t_c = C(R1_{meas}) \quad (2)$$

Table I uses the UL 1950 capacitor discharge criteria. The peak voltage, V_{pk} , was calculated using equation 3, with a 20% safety margin for the ac mains input voltage.

$$V_{pk} = (\sqrt{2})[240 \text{ V rms} + 0.2(240 \text{ V rms})]$$

$$V_{pk} = 407 \text{ V rms} \quad (3)$$

The capacitor voltage, V_{cap} , is to be 37% of V_{pk} after one time constant. Equation 4 derives the calculated capacitor voltage at any given time.

$$t = \text{time in seconds}$$

$$R = R1$$

$$V_{cap} = V_{pk}e^{(-t/RC)} \quad (4)$$

The measured V_{cap} is within a few volts of the calculated value. Even though $R1$ was not physically placed in the ac filter, 10 M Ω was

measured. The resistance was the resistance of the scope probe. Product safety engineers still must take into account the resistance value of the probe when calculating t_c , because the probe is parallel with $R1$. Use a probe with a resistance at least 10 times greater than that of the shunt resistor. Figure 2 shows the discharge voltage of filter no. 1 after one time constant.

Current Leakage

To minimize the calculated error for $I_{leakage}$, each Y capacitor was measured with a network impedance analyzer. To maintain a safety margin of 10% for the ac mains input frequency, the analyzer was set to 66 Hz. $I_{leakage}$ included the contribution of current from the power cord and the ac filter construction, 18 μA and 3 μA , respectively. For $I_{leakage}$ (equation 5) the variables are as follows: $E_{leakage}$, the input voltage to the circuit when measuring for leakage current, equals 288 V rms; $f_{leakage}$, the frequency of the ac voltage input when using a variable ac power source, equals 66 Hz; and C represents the capacitance of C1 or C2 in nF. $I_{leakage}$, the leakage current through one of the Y capacitors, was calculated and measured for each Y capacitor, C1 and C2. This was done by reversing the mains polarity.

$$I_{leakage} = E_{leakage}/(1/2\pi f_{leakage}C) \quad (5)$$

Typical Y-capacitor values of 3.3–4.7 nF result in leakage less than the 3.5 mA limit (see Table II). Because filter no. 4, however, has larger Y capacitors, its leakage current exceeds most safety standard requirements. Product safety engineers must account for more than the stated value of capacitance. The positive capacitance tolerance value is equally important. The Y capacitors set the current leakage, but the added tolerance could cause excess leakage.

Ac filter	$I_{leakage}$		Y-capacitor system measured at 66 Hz	
No.	Calculated	Measured	Y capacitor, C1	Y capacitor, C2
1	570 μ A	568 μ A	4.6 nF	4.6 nF
2	558 μ A	556 μ A	4.5 nF	—
	606 μ A	603 μ A	—	4.9 nF
3	439 μ A	435 μ A	3.5 nF	—
	427 μ A	432 μ A	—	3.4 nF
4	4.07 mA	4.05 mA	33.9 nF	33.9 nF

Table II. Current leakage.

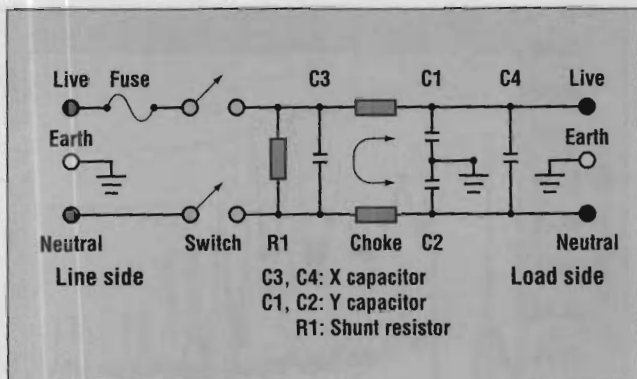


Figure 1. Schematic of an ac filter.

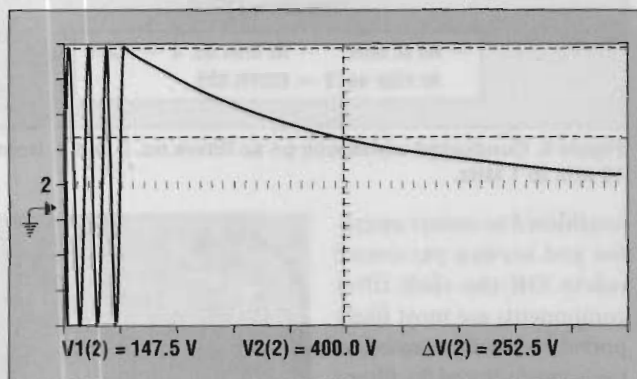


Figure 2. Discharge voltage of filter no. 1 after one time constant.

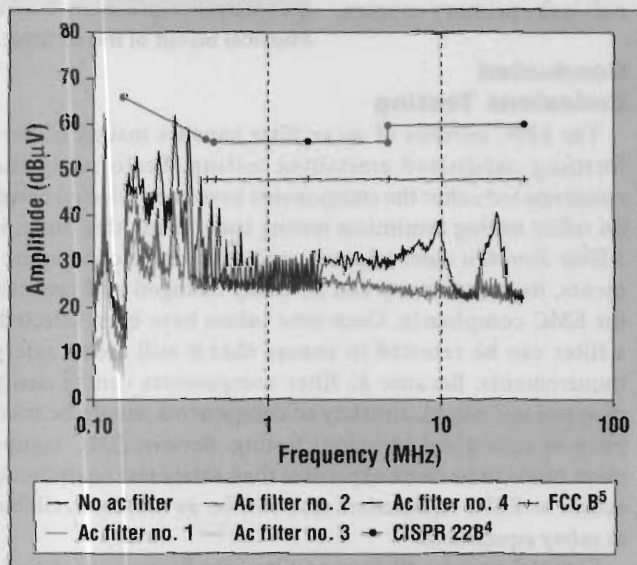
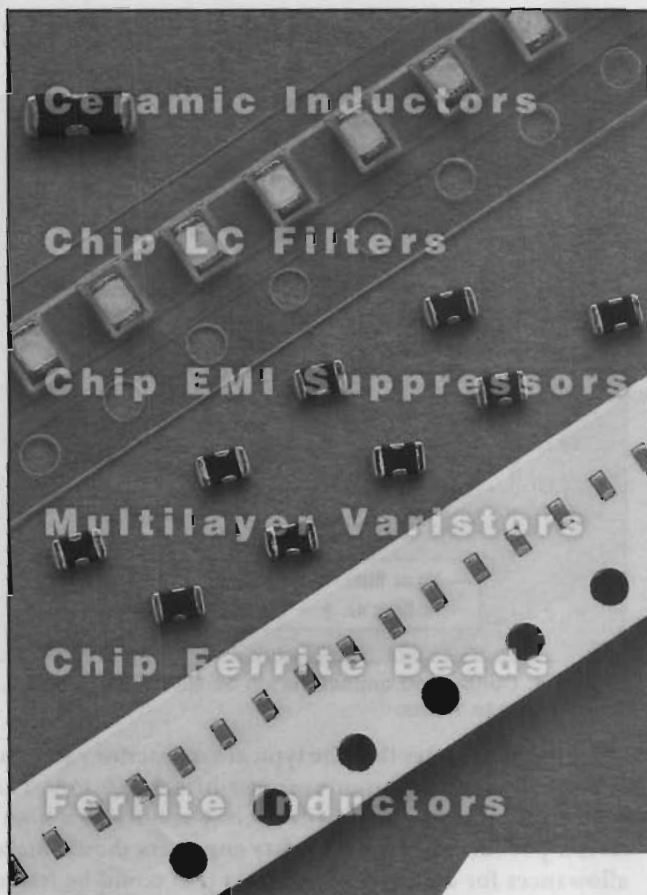


Figure 3. Conducted emissions on the four ac filters.

Dielectric Strength (Hipot)

From the previous current leakage experiment, we obtained the $I_{leakage}$ for each of the ac filter configurations: E_{hipot} , the voltage to which the hipot equipment is set, equals 1500 V rms; $E_{leakage} = 288$ V rms; f_{hipot} , the frequency of the hipot equipment, equals 60 Hz; and $f_{leakage} = 66$ Hz. If the Y capacitors were not equal, the $I_{leakage}$ was calculated to be the average measured current flowing through each Y capacitor.

$$I_{hipot} = 2(E_{hipot}/E_{leakage})(f_{hipot}/f_{leakage})I_{leakage} \quad (6)$$



CTC CERATECH CORPORATION

Ceratech is one of the only manufacturers in the world with 100% lead-free chip inductors with 100% tin plating. Ceratech offers a full line of Ceramic Inductors, Chip LC Filters, Chip EMI Suppressors, Multilayer Varistors, Chip Ferrite Beads and Ferrite Inductors.

Ceratech's Ceramic Inductors have typical Q's as high as 80 at 800MHz (0603 size) which lead the industry. A full line of 0402 Ceramic Inductors are available now with 0201 Inductors available in early 2001.

Ceratech's proprietary laminated ceramic material ensures high SRF, superior Q and excellent reliability. And because Ceratech is an engineering driven company, from the top down, you can be assured of the highest quality state-of-the-art products and product customizing capabilities with extraordinary design cycle times.

Ceratech has just completed a third factory with a fourth scheduled to be completed in 2001. With Ceratech's increased capacity, lead-time is not an issue NOW or in the future.

ISO9001 and QS9000 approved.

EXCLUSIVELY FROM



WORLD PRODUCTS INC.

P.O. Box 517
19654 Eighth St. East
Sonoma, CA 95476-0517 USA
Phone: (707) 996-5201
Fax: (707) 996-3380
www.worldproducts.com
ppgsales@worldproducts.com



Ac filter No.	R1	X capacitors		Y capacitors		Choke
		C3	C4	C1	C2	
1	330 k Ω	0.33 μ F	0.33 μ F	4.7 nF	4.7 nF	1 mH
2	417 k Ω	0.10 μ F	0.10 μ F	4.9 nF	4.9 nF	2.5 mH
3	1 M Ω	0.47 μ F	0.47 μ F	3.0 nF	3.0 nF	2 $\times$ 50 μ H
4	1 M Ω	0.47 μ F	0.47 μ F	33 nF	33 nF	2 $\times$ 50 μ H

Table IV. Ac filter components.

attenuation. Once those values are known, it is much easier to identify off-the-shelf ac filters that closely match engineered values. When selecting off-the-shelf filters, it is also important to consider the filter's mechanical size and ensure that the chokes can handle the current.

Conclusion

The components used in a line filter can create problems for safety engineers, but with capacitance reduction and proper choke selection, most product safety problems can be avoided. Selecting parts based on safety requirements provides the parameters for identifying filter options for conducted emissions testing. By fabricating an ac filter with components that can be easily substituted, engineers can experiment with a variety of configurations and quickly determine whether specific

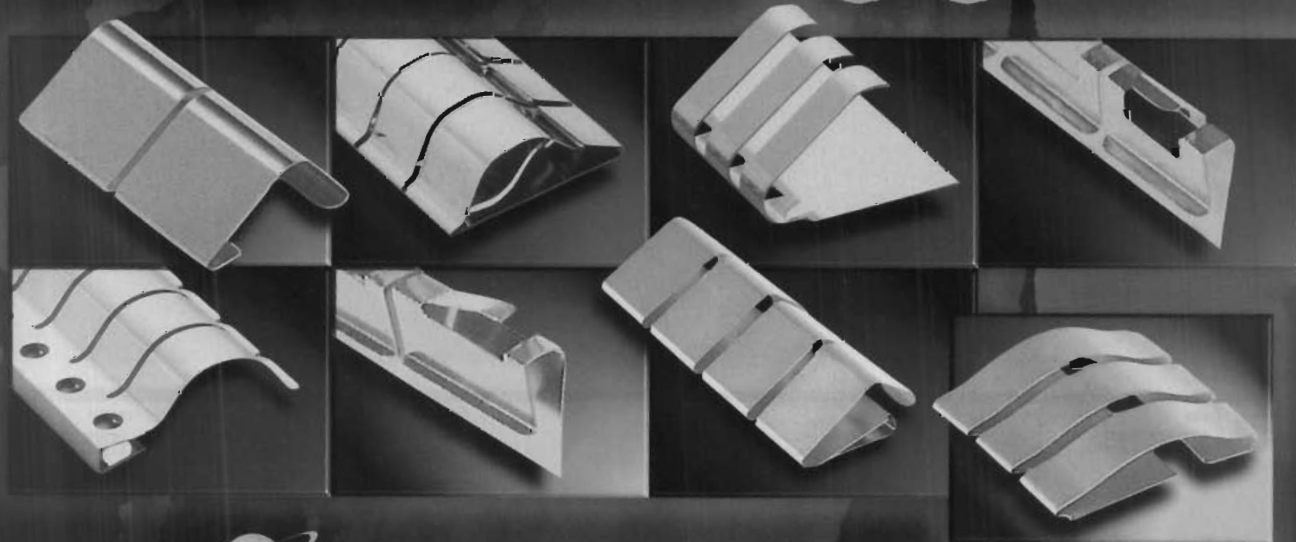
component values will meet both safety and EMC requirements.

References

1. Richard Georgerian and Ron Duffy, "Product Safety and Electromagnetic Compatibility Requirements of an A.C. Filter," in *Proceedings of the IEEE EMC Symposium* (Washington, DC: IEEE EMC Society, 2000), pp 845-850.
2. UL 150, 3rd ed., "Safety of Information Technology Equipment, Including Electrical Business Equipment," Underwriters Laboratories, Englewood, CO, 1995.
3. EC 61010-1, "Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use," International Electrotechnical Commission (IEC), Brussels, 1990-1999.
4. CISPR 22:1997, "Information Technology Equipment—Radio Disturbance Characteristics—Limits and Methods of Measurement," IEC, International Special Committee on Radio Interference (CISPR), Geneva, 1997.
5. "Unintentional Radiators," *Code of Federal Regulations*, 47 CFR Part 15, Subpart B (October 1, 1999): pp 667-692.

Richard Georgerian is a product compliance engineer at Exabyte Corp. (Boulder, CO) and can be reached at richardg@exabyte.com. Ron Duffy is a product safety engineer at Agilent Technologies Inc. (Colorado Springs, CO) and can be reached at ron_duffy@agilent.com. ■

emi-rfi shielding gaskets



OMEGA SHIELDING®
PRODUCTS

9 Emery Avenue • Randolph, NJ 07869 • tel: 973-366-0080 • fax: 973-366-8232
e-mail: sales@omegashielding.com • web site: www.omegashielding.com
ISO 9002 Certified

High-performance copper alloy gaskets and Omega Shielding - two standards of measurement which denote excellence in electronic enclosure shielding.